III-Nitride LED Modulation Measurements: Differential Quantum Efficiency, I-V Characteristic and Overheating

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A novel technique for direct measurement of differential quantum efficiency, differential I-V characteristics and temperature of light emitting devices was suggested. The key feature of the technique is the use of optically connected pair: LED - photodetector, where small modulation current is added to the direct current via the LED. The photodetector detects the modulated output optical signal from the LED. In this case, the alternating part of the detector current I_{PD} is proportional to the differential quantum efficiency of the device:

$$I_{PD} = A\frac{dL}{dP} = A\eta ,$$

where η is the differential quantum efficiency, L is the output optical power, P is power consumed by the LED and A is a constant dependent of the setup geometry and applied voltage.

Using this technique, we can measure directly the relative contributions of radiative and non-radiative recombination processes at different applied voltage. This technique also allows to obtain the relative temperature variations, overheating, with current by measuring of the differential I-V characteristics.

In the report, we will present the results of the differential quantum efficiency measurements for commercial III-nitride blue LEDs and also for our III-nitride blue LED with Charge Asymmetric Resonance Tunnelling, Fig.1.

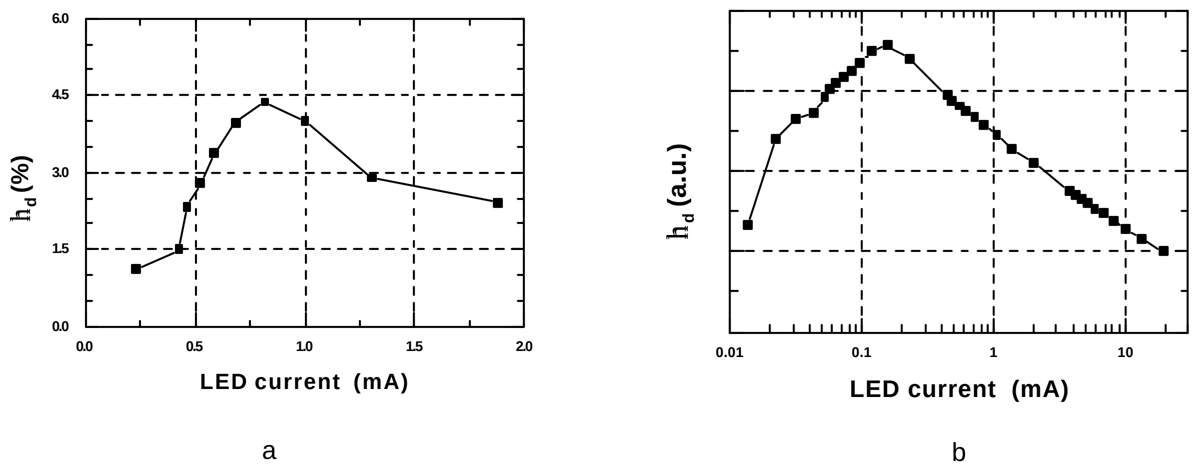

Fig. 1. Differential quantum efficiencies of III-nitride blue LED with Charge Asymmetric Resonance Tunnelling structures (a) in comparison with a commercial blue LED structure (b).

The differential I-V characteristics for III-nitride blue LED with Charge Asymmetric Resonance Tunnelling (a) and for a commercial III-nitride blue LED (b) are shown in Fig 2. The non-ideality factor n =4-8 indicates significant contribution of tunneling processes into the carrier transport.

The measurement of the differential I-V characteristics in the two different frequency ranges $\omega << 1/\tau_{th}$ and $\omega >> 1/\tau_{th}$, where $\tau_{th} = c\rho d^2/\kappa$, c – is the thermal capacity, ρ - is the density, d – is the thickness of the epilayer and κ - is the thermal conductivity, allows to determine the overheating of the device active layer. Our first experiment

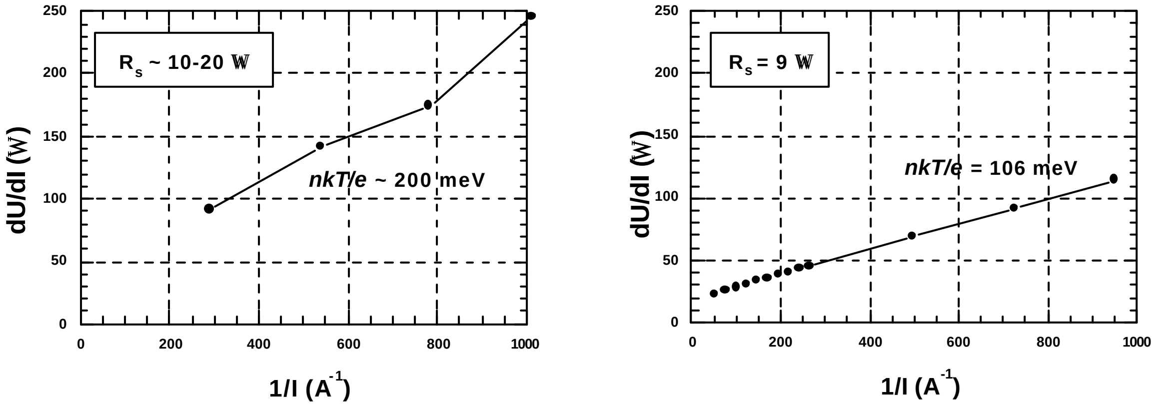

Fig. 2. Differential I-V characteristics of III-nitride blue LED with Charge Asymmetric Resonance Tunnelling structures (a) in comparison with a commercial blue LED structure (b).

shows that overheating start to influence the CART LED performance at the current density higher then 30 A/cm^2.

Thus, the suggested modulation technique for measurement of differential quantum efficiency, differential I-V characteristics and temperature of light emitting devices is very useful for detailed investigation of GaN light emitting devices.